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Breathing Movement Classification Using MFCCs

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Abstract

Detecting the breath and classifying breathing movements such as inhale and exhale has settled importance in many biomedical research areas. To this end, monitoring the breathing movements for lung cancer patients tends to remain one of the breath detection applications which have received much attention. On the other hand, virtual reality (VR) revolution has a lot of implications in many fields, which could also be used as a simulation technology for healing purposes. This has been an indication to use VR to assist the lung cancer patients.

In this work, a novel method is proposed to detect and classify breathing movements. In our technique, we employ Mel-Frequency Cepstral Coefficients (MFCCs) to the acoustic signal of respiration captured using a microphone to depict the differences between the inhale and the exhale in frequency domain. MFCC features are widely used in depicting the different acoustic and physical traits of voices.

For each subject, the acoustic signal of breath is captured and then split into inhale and exhale durations. We have applied 13-MFCCs for each inhale and exhale time-frame, and plotted the i-th MFCC for all subjects individually. We classify the movements using the 6th MFCC order which carries important classification information. Experimental results on a number of individuals verify our proposed classification methodology.

The proposed virtual therapy platform encourages the patients to regulate their breath as the system is identifying/classifying the breathing movements in real-time, and therefore, indirectly assists lung cancer patients to destroy the cancerous cells in a virtual environment.

Introduction

Motivation

The increasingly high volume of common cancer patients, has urged many researchers in medical and engineering fields to investigate the prevention and treatment/cure techniques more seriously. Lung cancer diagnosed patients are considered to have the highest prevalence among all cancer types. On the other hand, detecting breathing movements in real-time and associating these movements with a VR interface for patients is a big challenge (Figure 1).

Figure 1. Smart-phone application of the proposed platform.

Main Contribution

In this work, we use MFCC features to portray the differences between the inhale and the exhale in frequency domain. MFCC has the ability to fully capture the characteristics of the channel spectrum and simulate the human's auditory function, whose approximation of speech is linearly spaced in frequency scale.

Previous Work

One of the approaches to differentiate inhale from the exhale is to identify the maximum amplitude the signal reaches combined with the number of maximum peaks; however this technique is hard to implement and is also unreliable, since it requires continuous modifications for the marking coefficients regarding the breath signal (Figure 2).

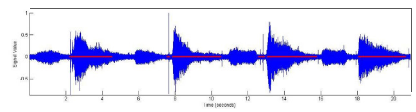

Figure 2. Exhale detection by maximum amplitude

Another more reliable technique is implemented by calculating the average energy of the signal per phase time, which also depends on the whole period of the breathing phase (Figure3) .

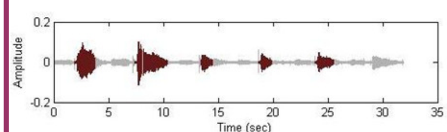

Figure 3. Exhale detection by average energy.

Methodology

All previous techniques work properly if the difference in amplitude and average energy of the exhale is higher than inhale. However, it's noted that in many acoustic signals of the breath, the inspiration phase has higher amplitude and average energy than the expiration, as shown below.

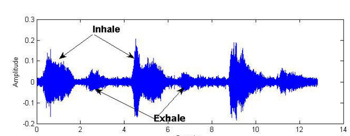

Figure 4. Breath cycles for an athletic player showing higher inhale average energy than exhale.

Procedure

The following steps show the classification procedure in our approach.

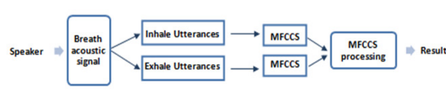

Figure 5. Block diagram of the proposed breathing movement classification

- First, the recorded signal for each speaker is split into ten inhales and ten exhales. The splitting process was implemented using the Audacity software. The inhale and exhale are cut from the middle of the pause phase between them.
- Second, the 13-MFCCs for each inhale and exhale of the same speaker are calculated.
- Third, the *i*-th MFCC of all samples is determined and kept aside from the other MFCCs.
- Finally, all the *i*-th MFCCs that are related to the same speaker's inhales and exhales are plotted.

The above procedure, as illustrated in Figure 5, is applied to all speakers and the results follow.

Results

The results shows that there are no obvious features that can be extracted from the 1st-5th and 7th-13th MFCCs since these values are very close to one another for the inhale and exhale. However, it's noted that the 6th MFCC for the exhales of the same speaker are very close to each other, similarly, the same also applies for the inhale values, and consequently, they could be separated using a linear threshold function as shown in Figure 6 below:

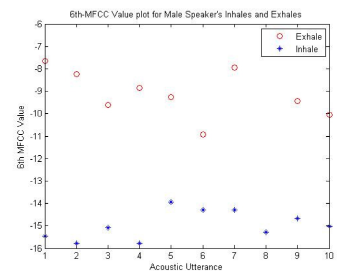

Figure 6. The 6th MFCC value for inhale and exhale classification of the same speaker

Table I shows the result of the inhale and exhale classification process using the 6th MFCC value. The Table contains the results of ten speakers

Speaker	Classified utterances	Misclassified utterances	Greater 6th MFCC values for	Accuracy (%)
1	10	0	Ex	100
2	10	0	IN	100
3	10	0	IN	100
4	9	1	Ex	90
5	10	0	Ex	100
6	10	0	Ex	100
7	10	0	Ex	100
8	10	0	Ex	100
9	10	0	IN	100
10	10	0	Ex	100
EX= Exhale, IN= Inhale.				

TABLE I. Breathing Movement Classification Accuracy for ten different speakers

Employing a linear threshold, could classify inhales and exhales within 90-100% accuracy. However, it should be known which values are greater than the other for final classification.

It's also noted that most of the speakers have the 6th MFCC values for exhale that are greater than inhale, with an accuracy of 80%.

Conclusion

Breathing cycle consists of four phases, the inspiration and the expiration phases which are surrounded by silence phases. Silence phases can be detected using segmentation and silence detection techniques which cut the breathing movement detection task into half.

By studying the inhale and exhale phases, it was observed that the 6th MFCC shows distinction among all the other MFCC in classifying inhale from exhale, as the values are very close for the same speaker's inhale or exhale phases. As a future direction, we plan on making use of a patient- adaptive threshold which will increase the accuracy of classifying the inhale and exhale phases to 99% and higher. In addition, we plan to integrate this classification technique with the smart-phone application to aid lung cancer patients regulate their breath.

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